Impact of Generation and Load Patterns on the Central Western European Flow Based Market Coupling

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Overview

In order to achieve the target model of a single European market, power markets have been gradually integrated and coupled at a regional level as of 2006 with the first market coupling of the Belgian, Dutch, and French day-ahead markets. The last major step towards the target model was the introduction of the so-called Flow Based Market Coupling (FBMC) in Central Western Europe (CWE) back in 2015. As market integration progresses, market results become increasingly dependent on particular generation and load situations in countries concerned. So far, wind power generation has been identified as a main driver of commercial exchange capabilities and cross-border power flows (cf. e.g. [1] and [2]). In fact, the increasing level of wind infeed with very low marginal cost in Germany has led to considerable price differentials between areas and corresponding export flows in recent years. In line with this development and due to limited cross-border exchange capabilities there is an increasing frequency of low or negative market prices in Germany. However, there is also an increasing frequency of (extremely) high market prices in the CWE region, that cannot solely be attributed to excess supply due to wind infeed in Germany. There is reason to believe that decreasing levels of conventional generation as observed in France and Belgium in recent years could provide an explanation for these high prices and corresponding cross-border exchanges. Against this background, we propose a statistical model framework to study the relationships between generation and load patterns and commercial exchange capacities and market outcomes in Central Western Europe.

Methods

The procedure implemented in this study can be divided into three major steps. **(I.)** First, based on the design of the FBMC in CWE relevant dependent and explanatory variables are identified. Different sets of dependent variables are formed by the outcomes of the subsequent stages of the capacity allocation process, i.e. commercial transaction constraints and resulting cross-border power flows. The explanatory variables comprise variables describing the generation and load situation in the CWE region. Due to the focus on spot markets in the day-ahead timeframe, forecasts of the respective variables are considered.

$$\hat{p}_t = \frac{\widehat{W}_t}{\hat{L}_t} \qquad (1)$$

where $\widehat{W}_t$ is the wind power production forecast and $\hat{L}_t$ the load forecast for Germany. While the German power system is characterized by a high share of variable wind power production, the conventional generation (mainly nuclear) and load situation in France is considered to likewise impact the market coupling.

$$\hat{c}_t = \frac{N_t}{\hat{L}_t} \qquad (2)$$

where N_t is the generation from nuclear plants and $\hat{L}_t$ the load forecast for France. Further variables like the generation and load situation in Belgium and the Netherlands can be included accordingly. All these variables are available in hourly resolution in the considered data set for the period from May 2015 to May 2018.

(II.) Second and where necessary, the complexity of the multivariate data is reduced using principal component analysis (PCA). In particular when analysing a large number of flows the dimensionality of the problem increases, which is why the subsequent statistical regression is employed on a reduced basis of the original dataset. In order to identify the principal components Y_i (PCs) accounting for most of the variance in the flow dataset, the covariance matrix of the centered flows is computed and eigenvectors according to the corresponding eigenvalues are selected. The original flows can then be written as a linear combination of the PCs Y_i plus an error term ε_t. In order to account for the effect of the explanatory variables (see first step) the coefficients α_i of the PCs are allowed to vary as functions of the explanatory variables u_t with $u_t = [\hat{p}_t, \hat{c}_t]$:

$$\tilde{X}_t = \sum_{i=1}^{n} \alpha_i\,(u_t) Y_i + \varepsilon_t \qquad \forall t \qquad (3)$$

(III.) Third, multivariable polynomial regression is applied to study the dependence structure between generation and load patterns and sets of dependent variables, i.e. *export capabilities* and *commercial cross-border flows* [2].

Results

The results of the PCA (step II.) applied to the *commercial cross-border flows* reveal that most of the original variance can be explained by a limited number of PCs (see ***Table 1***). Consequently, selecting the first i PCs allows achieving a similar statistical representation of the orginal flow dataset and reducing the size of the problem. ***Figure 1*** provides further insight into the characteristics of the first PC, which is mainly described by commercial flows directly from Germany to France and Austria. Moreover, flows from Germany to France via the Netherlands and Belgium can be observed. As the first PC represents 29.2 % of the variance of the original flows, the focus will be on German export capabilities and commercial flows between Germany and France in the following.

Table 1*: Fraction of variance explained by the principal components for commercial cross-border flows*

Principal component	*Individual fraction of variance [%]*	*Cumulative fraction of variance [%]*
1	29.2	29.2
2	17.1	46.3
3	13.7	60.0
4	10.7	70.7
5	8.0	78.8
6	6.1	84.9
7	3.6	88.4
8	3.5	91.9

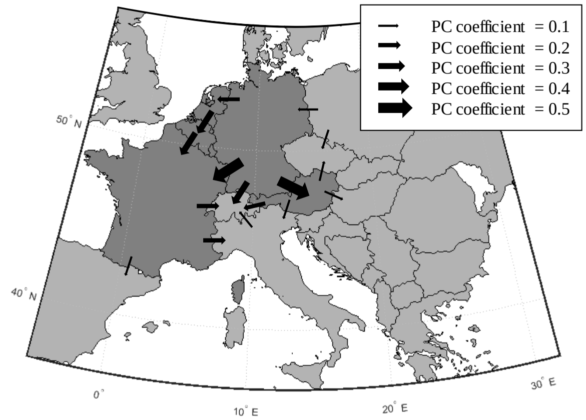

Figure 1*: Map of CWE showing the weights of the commercial cross-border flows in the first PC*

The regression analysis (step III.) confirms that the *export capability* of Germany depends on the wind penetration in Germany (see ***Figure 2a***). Accordingly, export capabilities decrease with an increasing wind penetration. However, the supply situation in France appears to likewise impact the export capability, as lower export capabilities are obtained with a decreasing share of nuclear generation. Consequently not only excess wind generation in Germany, but also supply scarcity in France negatively influences German export capabilities. The statistical model confirms the intuitive reasoning to which an increasing regional imbalance of supply and demand leads to grid congestion and lower commercial exchange capabilities in the CWE region. The results of the regression for *commercial cross-border flows* mirror this effect. As ***Figure 2b*** shows, high export flows from Germany to France are obtained for situations with high wind penetration in Germany and a high share of nuclear generation in France reducing north-south congestion in the CWE region.

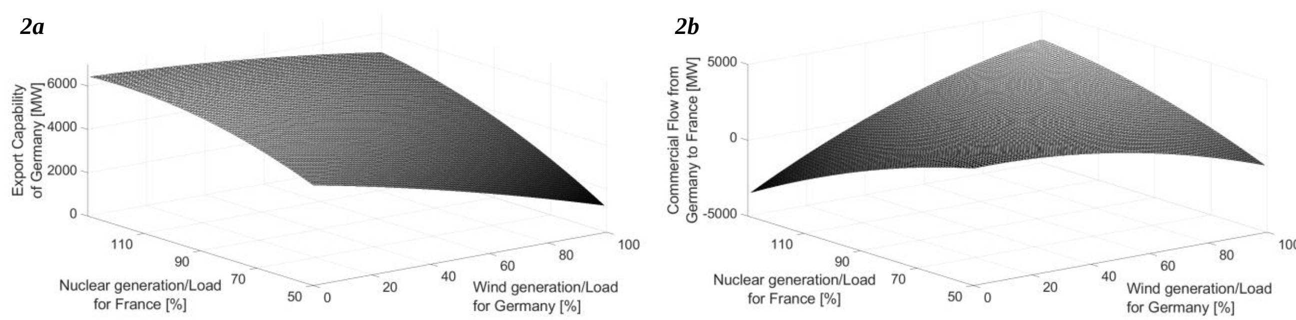

Figure 2*: Regression on the Export Capability of Germany (Maximum Net Position) and Commercial Flow from Germany to France (Day-ahead Bilateral Exchange) relative to wind penetration in Germany and nuclear generation in France*

Conclusions

In this contribution, we analyse the impact of generation and load patterns on the CWE FBMC using a statistical model. First results reveal the importance of cross-border flows between Germany and France in a regional context. It could be shown that not only excess wind generation in Germany, but also supply scarcity in France affects German export capabilities and commercial flows. Further analyses will incorporate more/other variables and extend on the sensitivity of the results to non-stationarity of the data.

References

[1] M. Bucksteeg, K. Trepper and C. Weber (2015). "Impacts of renewables generation and demand patterns on net transfer capacity: implications for effectiveness of market splitting in Germany," in IET Generation, Transmission & Distribution, 9 (12), pp. 1510-1518.

[2] M. Zugno, P. Pinson and H. Madsen (2013). "Impact of Wind Power Generation on European Cross-Border Power Flows," in IEEE Transactions on Power Systems, 28 (4), pp. 3566-3575.